OPTIMUM WAVELENGTH INTERVALS FOR SURFACE TEMPERATURE RADIOMETRY

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Abstract:

Total reflectance measurements of some common surface minerals in the wavelength interval 0.5 to 23 microns show pronounced reflection maxima in some regions used for radiometric measurements of planetary and lunar surface temperatures. Variations in emissivity in the regions of such maxima could introduce significant errors into such temperature measurements. If measurements are restricted to the "windows" in the atmosphere of earth the 10 to 12 micron interval seems the best choice for radiometry since, in this interval, minerals are most uniformly "black".

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Introduction

Infrared radiometric measurements of the surface temperature of earth, the moon and those planets whose surface is accessible are generally made under the assumption that the surface emissivity is nearly unity in those wavelength intervals where the atmosphere of earth is transparent. The 8 to 14 micron "window" is the most widely used for such radiometry. Total reflectance measurements of a variety of surface minerals show that large departures from unit emissivity may occur but that these departures are generally confined to specific spectral regions and can be avoided by a careful choice of wavelength intervals.

Reflectivities from 0.5 to 6 microns of some of the samples reported here have been described in an earlier paper (1) concentrating on the spectral region where reflected solar energy would be expected to be the predominate source of observed radiation in daylight hours. At longer wavelengths, where emitted thermal energy will predominate, total reflectance measurements are an indirect measure of emissivities. Since total reflectance over an entire hemisphere is measured, with inconsequential specimen heating, this may very well be a more accurate method of determining spectral emissivities than heating specimens well above room temperature and measuring direct emission over a considerably smaller solid angle.

Experimental Procedure

The total reflectivity of all specimens was measured with a Beckman DK2A spectrophotometer equipped with a total reflectance attachment in the 0.5 to 2.5 micron wavelength interval. Measurements from 2.5 to 22 microns were made with a Cary Model 90 double beam spectrophotometer equipped with the total reflectance attachment described by White (2).

Results

Measurements are reported here for a variety of pure minerals and a number of natural surface covers containing these materials.

Figures 1 through 5 show the reflectivities of calcium carbonate, calcium sulfate or gypsum, sodium chloride, sodium carbonate and sodium nitrate. A large number of spectral absorption bands are seen all through the region of measurement. Both carbonates have a prominent absorption near 11.2 microns in coincidence with the unexplained feature obtained by Sinton and Strong (3,) in thermal emission spectra from Venus.

Calcium sulfate or gypsum is relatively "black" from 8 to 14 microns, but pure salt is highly reflecting despite an appreciable amount of water present in the sample.

The reflection spectrum of sodium nitrate is incredibly complicated but since it is not a major surface material of earth except for certain regions of Chile, it will not present much of a problem to radiometry.

Quartz sand from beach areas and deserts exhibits residual rays in the 8 to 10 and 18 to 22 micron regions that result in a considerable localized increase in reflectivity and consequent decrease in emissivity. Figures 6, 7 and 8 show the reflectivities of sand from Atlantic City, New Jersey and Daytona Beach, Florida and sandy soil from the Mojave Desert of California. Since the intensity of residual ray features is not constant but varies with particle size as in the silica sand shown in Figure 9 the spectral region containing residual rays of quartz should be avoided in surface temperature radiometry.

Specimens from various areas of Western United States have been examined, especially these areas with minimal vegetation coverage and, hence, minimal seasonal change in characteristics.

Samples of the Salt Pool and Bad Water areas of Death Valley were preserved intact and reflectivities measured as shown in Figures 10 and 11. A small impurity concentration has greatly reduced the reflectivity of salt as found in the Salt Pool from that seen in pure salt.

Natural gypsum, distributed through much of the surface cover of Western United States, is highly concentrated in the sands of White Sands National Monument. Reflectivity of this sand, shown in Figure 12, shows a pronounced maximum at 8.6 microns.

The reflectivity of soils from the Pawnee Grassland of Colorado and Rosamond Dry Lake in California show mild residual ray maxima in the 8 to 10 micron region as shown in Figures 13 and 14 and are reasonably "black" at longer wavelengths.

Conclusions

Natural surface minerals of earth may, in the wavelength region of atmospheric windows, have emissivities significantly less than one. Within the 8 to 14 micron window lie residual ray reflections, due mainly to quartz, that may reduce emissivities to as low as 0.55 as in the Daytona Beach sand.

The most intense residual ray maxima, in the window, are at wavelengths shorter than 10 microns. Choice of a wavelength interval between 10 and 12 microns seems optimum, for surface temperature radiometry, since it avoids the stronger residual rays and has the additional advantage, for satellite radiometry and earthbased radiometry of the moon and other planets, of avoiding absorption effects by the ν_1 band of ozone at 9.59 microns.

References

(1) Hovis, W. A., Infrared Reflectivity of some Common Minerals, Applied Optics, In press.

(2) White, J. U., New Method for Measuring Diffuse Reflectance in the Infrared, J.O.S.A., 54, 1332, (1964).

(3) Sinton, W. M. and Strong J., Radiometric Observations of Venus, Astrophysical Journal, 131, 470 (1960)

Caption of Figures

Figure 1	Infrared	Reflectivity	of	$CaCO_3$
Figure 2	"	"	"	$CaSO_4 \cdot 2H_2O$
Figure 3	"	"	"	NaCl
Figure 4	"	"	"	Na_2CO_3
Figure 5	"	"	"	$NaNO_3$
Figure 6	"	"	"	Atlantic City, N.J. Beach Sand
Figure 7	"	"	"	Daytona Beach, Fla. Beach Sand
Figure 8	"	"	"	Mojave Desert Soil
Figure 9	"	"	"	Washed Silica Sand
Figure 10	"	"	"	Salt Pool, Death Valley, California
Figure 11	"	"	"	Bad Water Clay, Death Valley, Calif.
Figure 12	"	"	"	Gypsum Sand, White Sands, N.M.
Figure 13	"	"	"	Soil, Pawnee Grassland, Colorado
Figure 14	"	"	"	Soil, Rosamond Dry Lake, California